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the formulæ which the mathematicians have worked out, and still harder to understand them. But, undoubtedly, the reward is rich. It is not only that we thereby secure accurate data upon important questions. It is, furthermore, not a 'mere formal clothing of biological conceptions with mathematical symbols.' Such analysis tends to crystallize our notions and makes our conceptions more definite; it will open up new lines of thought, and carry us toward the ultimate goal of a complete understanding of the mechanics of evolution. As in all valuable lines of thought the pitfalls are many, but progress is certain. "Ignoramus; in hoc signo laboremus!"

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DISCUSSION

THE APPLICATION OF CALCULUS TO MENTAL PHENOMENA

IN one of Dr. Montague's recent publications on time perception it was pointed out that we can get a very simple expression for the 'specious present,' which was found to be $\frac{do}{ds}$, if we denote by o the objective and by s the subjective elements of a psychosis. The second derivative would determine the time flow. Without considering the important philosophical results of the theory we shall make the following observations about the method.

The author considers the ratio of the increments Δo and Δs, which occur in the time Δt, and the fraction $\frac{\Delta o}{\Delta s}$ is supposed to approach or attain the limit $\frac{do}{ds}$. It will be of some interest to see what suppositions this statement involves. First of all it is clear that we have to consider the limit of $\frac{\frac{\Delta o}{\Delta t}}{\frac{\Delta s}{\Delta t}}$, because o is not an explicit function of s. Though we know little or nothing about the sufficient conditions of differentiability, we can in this case readily indicate the following necessary conditions: (1) o and s must be continuous; (2) both must have a differential quotient with regard to t; (3) both differential quotients must be continuous; (4) $\frac{ds}{dt}$ must not be zero in the whole time interval under consideration. It is hard to make those assumptions, when we know nothing about the character of the functions dealt with, especially since s is apparently discontinuous in many points and can not be submitted to the well-known tests.

It is evident that the author had in mind to measure a time period by its relation to a standard change and so to get rid of duration, but he did not see that the conditions of the problem became so much more complicated by the implicit relation of o and s. All these tacit presuppositions would have become clear if the author had assumed that o is an explicit function of s, but such a relation, of which we can get no idea, would never have been granted. The establishing of the indirect relation between o and s by introducing them as functions of time hides the difficulty but does not remove it.

An example will show to what kind of conclusions we come, if we accept the author's view. $\frac{do}{ds}$ varies with time and we may pick out two moments for which this ratio has the same value, as it is always possible because $\frac{do}{ds}$ is continuous and $\frac{d^2o}{d^2s}$ changes sign. The conditions of Rolle's theorem are fulfilled, since continuity of $\frac{do}{ds}$ and existence of the second derivative are supposed by the author, and therefore the second derivative vanishes at least once. The vanishing of $\frac{d^2o}{ds^2}$ is characteristic for the state of ennui and the first conditions are approximately fulfilled if one sits in a quiet room and recalls something. It follows that one must be bored before one can recall anything. Psychological laws of this kind can be deduced easily by every mathematician.

There is not the least doubt that the whole theory of functions could be applied to a psychology of this kind, but the question remains, whether the conclusions logically deduced from our system admit of a verification by experiment. If we consider it an important feature of experimental psychology, that to every implication of our system corresponds an empirical fact and—if possible—*vice versa,* we must renounce speculations about functions of which we know nothing.

Now supposing for a moment that there are no gaps and errors in the author's proof, could we deduce anything from his laws? Of course not. The function is totally unknown and we must measure empirically the value of $\frac{d^2o}{ds^2}$. It would be important to know the derivative if we could construct the function or if we could verify it in some other way, but as we can not we must conclude that the use of symbols of which the applicability is uncertain and the meaning too general is of little help in psychology.

Finally it may be mentioned that the interesting attempt to measure a time period by the ratio of a change occurring in it to a standard change also occurring in it fails, because this ratio is a number which becomes a time only when multiplied by a time unit. For such a standard we choose a certain amount of change in *o*, to which we refer as a standard, for instance the movement of a pendulum. One of the principal features of a standard is constancy, and measurement is impossible without it. We have therefore either a measurement which varies with time or our whole speculations about the specious present break down, because the differential quotient of a constant vanishes everywhere.

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REVIEWS AND ABSTRACTS OF LITERATURE

Some Peculiarities of Fluctuating and of Inaudible Sounds. KNIGHT DUNLAP. *Psychological Review,* Vol. XI., pp. 308–318.

The Effect of Stimuli upon the Traube-Hering Waves. C. E. GALLOWAY. *American Journal of Psychology,* Vol. XV., pp. 499–512.

The Effect of Closing the Eyes upon the Fluctuations of the Attention. BERTHA KILLEN. *American Journal of Psychology,* Vol. XV., pp. 512–514.

The last two of these articles can not well be discussed apart from a series of experiments that have been carried on under the general supervision of the reviewer, and it may therefore be well to take advantage of this opportunity to summarize the earlier results and the general theory which lead to the experiments and which they confirm and support.

This theory, first proposed by Dr. Slaughter in 1901, is, in outline, that the attention waves are related with two physiological rhythms, the rhythm of respiration and the rhythm of blood pressure or change in arterial volume variously known as the Traube-Hering or Sigmund Mayer waves. The evidence was direct. The stimulus appeared during the expansion of the blood-vessels and disappeared during their contraction. The correlation was confirmed by Bonser in ignorance of Dr. Slaughter's results, with the difference that he asserts that disappearance corresponds to expansion, appearance to contraction in volume. Study of his curves, however, indicates that usually the coincidence is not so direct, that the contraction usually begins during the period of appearance, and lasts well over into the time of disappearance. Further evidence is needed on this point, but it seems probable that the results are not so divergent as the verbal formulations would indicate.